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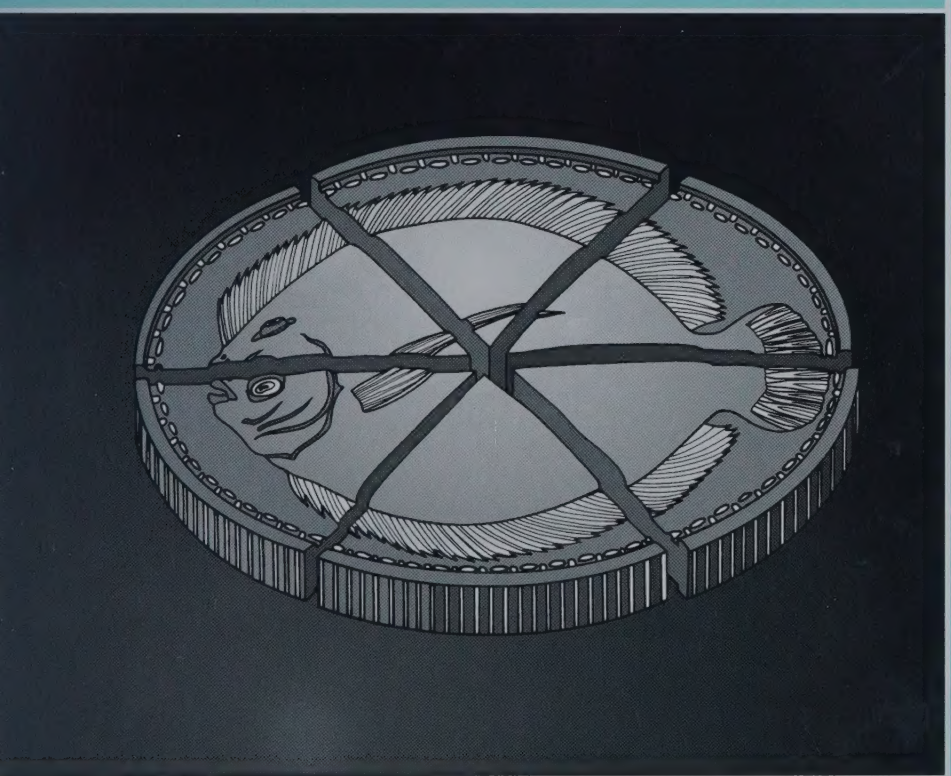
Individual quota management in fisheries

Methodologies for determining catch quotas and initial quota allocation



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Individual quota management in fisheries

Methodologies for determining catch quotas and initial quota allocation

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PREPARATION OF THIS DOCUMENT

This report was prepared in response to the increasing awareness of the central part that quota management plays in fisheries management. The Fisheries Department intends to continue publication of a series of reports examining different issues relating to quota management in fisheries.

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ABSTRACT

The management of fisheries by catch quotas has a long history in a number of areas and has been probably the most common method of controlling exploitation of fish stocks. However, in recent years, the technique of managing by global Total Allowable Catches (TACs) has not been able to address the rapid improvements in technology of harvesting and has therefore not generally been successful in limiting fleet capacity. This, combined with practical difficulties of monitoring and enforcing TACs, has resulted in a poor record in achieving fish stock sustainability and in optimizing the economic performance of fisheries.

However, recent advances in and adoption of the techniques of managing by Individual Transferable Quotas (ITQs), which provide greater incentives for sustaining and optimising economic performance of fisheries, have re-focused attention on quota management. The increasing interest in ITQ management has, however, not been matched by the availability of a theoretical framework for quota management which considers the various biological, economic and financial influences as part of an integrated management system.

This paper is the first of a projected series which examines not only this theoretical basis of quota (particularly ITQ) management as an integrated system but also draws on practical experiences in various parts of the world to provide guidance for agencies examining the issue of quota management in fisheries.

The present paper covers the biological, economic and financial issues which need to be considered in setting the Total Allowable Catch and in allocating that TAC both between participants in the fishery and between those participants and the regulatory agency. Later papers will address the issues of administration of the quota management system, compliance and surveillance issues and secondary markets for quotas.

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1. INTRODUCTION

Although management of fisheries resources by limiting catches through the imposition of catch quotas has a long history (and is often incorporated into traditional fishing practices), the theoretical basis for such quota management as an integrated management system has, surprisingly, not received much attention. In fisheries where quota management is the policy tool of choice, the basis for such quota management has usually been approached in a piecemeal fashion with traditional stock assessment techniques being used to assess the status of the stocks and to advise on 'appropriate' quotas or Total Allowable Catches (TACs). The determination of what is an 'appropriate' TAC is usually underpinned by a desire to ensure long-term sustainability of the particular fish resource but, beyond that, there has usually been no explicit consideration (apart from socio-political objectives) as to the impacts of various TAC levels (or the way in which the TAC is allocated) on overall economic performance of the industry, financial impacts on individual operators, etc. In some instances, although such occasions are still the exception rather than common practice, economic and financial information is assessed in determining TACs but the integration of these data and the biological processes which determines the productivity of an exploited fish stock is usually not considered.

Catch quota, or TAC, management where the catch quota is not individually assigned to operators in the fisheries has not had an impressive track record in either resource conservation or in economic optimization of fisheries. Of the 22 fisheries managed by catch quotas and monitored by the Organization for Economic Cooperation and Development (OECD), only 6 fisheries were maintained at steady catch levels, while 16 experienced declines or collapses at some point while under TAC management (OECD 1996) (Management by TACs has also had a poor record schemes in the countries of the European Union (Corten, 1996). TACs used alone were not able to prevent the collapses of herring stocks in British Columbia, Iceland or Europe.

Even when TAC management is supplemented with other regulations, including limited entry, the record in stock conservation or economic optimisation is not good. Of the OECD group of 22 fisheries managed by TACs, 11 were also subject to limited entry restrictions as well as additional restrictions on inputs in some of them. Three of the six fisheries which were maintained at steady levels were managed by combinations of TACs and limited entry while eight of the 16 fisheries which experienced declines were also managed by such combinations. The reason for this poor performance may be found in the prime characteristic of global TAC managed fisheries that such a management system provides strong incentives for increased competition between participants - the fishermen. This heightened competition is manifested in the development of a 'race-to-fish' approach where each individual operator seeks to maximize his efficiency to take as much of the available TAC as possible. In all of the quota managed fisheries monitored by OECD (OECD 1996) there was also strong evidence for this expected 'race-to-fish' as TAC management heightened the competition between individual operators. This resulted, in all fisheries, in increasing often already excess capacity and shortened fishing seasons. The race-to-fish also

resulted in reduced profitability, increased costs and capital stuffing[1] in all the monitored fisheries.

Management by catch quotas where these catch quotas are not assigned to individual operators (i.e. are not 'individual' quotas) therefore suffer significantly from inherent incentives which produce excess capacity, poor stock conservation and reduced profitability. These disadvantages have been well documented both from a theoretical point of view and from practical experience in a number of countries (OECD 1996; Corten 1996) with the result that simple quota management of fisheries by 'global' TACs is no longer a favoured approach to fisheries management.

However, more recent developments in quota management of fisheries, such as the introduction in countries such as New Zealand, Australia, Canada, the Netherlands and the United States of America of Individual Transferable Quotas (ITQs) have focused increasing and renewed attention on quota management and the way in which catch quotas may be determined, allocated and traded. In the short time that they have been implemented, individual quotas have generally been highly successful in reducing capacity, generating economic rent, improving quality and achieving increased profitability. Of the fisheries managed by individual quotas in the OECD countries (OECD 1996) and for which data were available, 22 fisheries provide evidence of economic rents being generated through positive quota values and none indicated the contrary. In addition, 23 of 24 fisheries managed under transferable quotas experienced increased profitability and reduced fleet capacity, while quality improvements were documented in all 13 fisheries for which data was available. The limited negative experiences with individual quota management related mainly to the initial allocation of quota.

This paper is the first in a series which will examine in detail the theoretical bases of individual quota management in fisheries as an integrated management system in which the relationships between biological, economic, financial and operational processes are explicitly considered. This involves a consideration of not only the broader implications of setting TAC but also, *inter alia*, the methodology and implications (biological, economic, operational and financial) by which the TAC is initially allocated to participants in a fishery, the mechanisms for ensuring continuing economic efficiency in the quota transfer process, quota administration, data requirements for individual quota management, compliance and monitoring issues including cost minimization, by-catch reduction mechanisms, etc. By approaching individual quota management in this integrated way, the series will provide direction for management of fisheries by individual quotas which address the entire management process (not just the biological processes) and will also be able to shed light on the causes of failure, in some areas, of past quota management schemes.

This paper addresses the important aspects of determining and initially allocating individual catch quotas (IQs) which are the essential precursors of any ITQ management arrangement. Details of the mechanisms for optimizing transferability and quota trading, reducing transaction costs, and compliance, monitoring and administrative issues, etc., will be the subject of subsequent papers.

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[1] Capital stuffing is a term often used for situations of over-capitalization where fishermen have increased the fishing power of their vessels by investing in larger engines and other enhancing changes.

2. QUOTA MANAGEMENT AND MANAGEMENT PERFORMANCE

Although catch quota management has been extensively used in fisheries to control exploitation and to optimize economic performance, its success has not been good in achieving these goals. In a recently completed review of management success in OECD countries (OECD 1996), 18 of 24 countries reported using quota management for at least some of their fisheries. Notable users were the European Union, through its Common Fisheries Policy and International Fisheries Commissions for the North West Atlantic (ICNAF and NAFO), the Baltic Sea (IBSFC) and for halibut (IPHC). These management authorities are notable for their extensive and lengthy reliance on quota management as a principle method for fisheries management, and in some fisheries (e.g. herring stocks in Canada) quota management arrangements have been in place for more than 60 years. Of 22 fisheries in 11 countries (Australia, New Zealand, Canada, Denmark, Finland, Iceland, Netherlands, Norway, Spain, UK and USA) which were examined, the stocks in only six fisheries have been maintained at steady levels compared with 16 that have experienced a stock decline or collapse during the period in which quota management has been in place. Management by catch quotas in the fisheries of the European Union has been particularly ineffective, and current management objectives in many European Union (EU) fisheries is merely to maintain the *status quo* of over-exploitation (Corten 1996). Most notable stock declines have been in the herring fisheries of Canada, Iceland and Europe, while the International Council for the Exploration of the Sea (ICES) have reported that fishing mortalities in most stocks in the ICES area have risen appreciably since the introduction of TACs and quota management (Anon 1995). Even when catch quotas have been used in conjunction with other measures such as limited entry (e.g. southern bluefin tuna of Australia, Polish hake fishery, Draganik and Wysokinski 1988), stock declines have been more common than maintenance of stock biomass levels in most fisheries.

2.1 Genesis of management failure

Management 'failures' in fisheries have generally been considered from a biological, or resource, point of view and from the socio-economic point of view. In a biological sense, 'failure' has been taken as the decline, or even collapse, of the fish stock as a direct consequence of the management regime, while from the socio-economic point of view, 'failure' is reflected in poor economic performance of the fishery and unacceptable equity consequences related to re-distribution of rights, power, opportunities and wealth.

Most biological failures of quota managed fisheries have been in situations where the catch quota has not been individually assigned to operators in a fishery but has been established as a 'global' quota. OECD (1996) reported that of the 22 fisheries in 11 countries. Economic performance was also poor in almost all of these fisheries. This may be compared with 23 of 31 fisheries in the same countries which were managed by individual quotas and which maintained catches at or below the TAC. Most fisheries managed by individual quotas also experienced substantial improvements in economic performance and in product quality.

However, even in fisheries managed by individual quotas, the critical issue of setting the TAC has not always been done well. OECD (1996) reports that in 24 of 37 stocks in 11 countries managed by individual quotas, TACs appeared to have been set too high, resulting in at least temporary declines in stock abundance. When Individual Transferable Quotas were

introduced in New Zealand, there was little information on the status of resources and that much information is still lacking both in New Zealand and in other countries that have introduced transferable quota management.

Based on an examination of fisheries which have implemented management by global catch quotas (as opposed to individual quotas), a number of reasons for the failure of quota management to achieve either stock conservation or optimal economic utilization of the resources become apparent. These may be summarized as follows:

- Increased competition among operators to take as much of the TAC as possible before the season is closed. This enhanced competition, or 'race to fish', is a particular problem with 'global' quotas and results in increased capacity, significantly shortened seasons, increased harvesting costs and reduced profitability. In addition, product quality can suffer significantly thus reducing revenues (Wilen and Homans, 1994). Total economic rent from the fishery declines as a result of excess capacity. Increased competition and its attendant effects have been documented (OECD, 1996) in 20 fisheries managed by 'global' catch quotas (e.g. US and Canadian Pacific halibut, Alaskan King crab, Australian bluefin tuna and gemfish, Canadian geoduck, etc.) with no counter examples. Halliday *et al.*, (1992) estimated that increasing capacity in the Nova Scotia inshore fleet had resulted in capacity levels which were approximately 4 times that required to exploit the groundfish stocks. Reduced profitability brought about by the enhanced competition in itself will often result in resource overexploitation because of increased financial pressures leading to illegal fishing, etc.

- *Difficulties of enforcement of TACs*
  Problems with enforcement of quotas apply equally to 'global' quotas and to individual quotas and may even be greater in individual quota- managed fisheries because of the additional surveillance requirements to monitor quotas at an individual vessel level. Of 21 fisheries managed by 'global' quotas for which information is available, only 7 have been able to keep actual catches at or below the recommended TAC. Catches exceeded the TAC in all the other 14 fisheries. Many of these enforcement difficulties, particularly in the European Union, (Corten 1996) relate to the multi-species nature of the fisheries and the consequent need, for stock conservation purposes, to set TACs for a number of species which are captured concurrently. Such a management process is, however, often impractical and ignores the realities of the harvesting process. This has lead to both a common practice in many fisheries of illegal landings and to the discarding of otherwise saleable fish because the quota for that species had been reached. Difficulties of enforcement have also been reported as a result of inadequate planning of compliance and enforcement programs to match the quota setting mechanisms. For example, in the Dutch beam trawl fishery, which takes a mixture of cod, sole and plaice, each of the 500 or so vessels had individual quotas assigned for each of the three species. Given that catches are landed frequently at a large number of fishing ports, the small number of fisheries inspectors were faced with an almost impossible task of enforcing these vessel quotas which inevitably resulted in a large scale practice of illegal landings an political crises (Corten 1996).

- *Inappropriate TACs*
  In setting the TAC for any quota managed fishery, whether it be a 'global' quota or 'individual' quotas, there have been numerous instances where the failure of the management process can be linked back to an inappropriate TAC. Inappropriate TACs may result from:

  i. The introduction of quota management into inappropriate fisheries, such as those with high by catch levels or in which a large number of species are captured simutaneously. This often stems from a lack of understanding of the operational aspects oft heindustry by the managers and scientists introducing the quotas (see below).

  ii. Inadequate capability and/or data for the provision of scientific advice and analysis on TAC levels. This was, and continues to be, a significant problem in many fisheries. When ITQs were introduced in New Zealand, there was little information available about the status of many stocks (such as orange roughy) and, as a result, TACs may have been set too high in some fisheries (Annala 1996). In Australia, the introduction of individual quota management was delayed in many fisheries because inadequate data existed to confidently establish TACs (Scott & Geen 1991).

  iii. Manipulation of the TAC in a negotiating context. Even when the scientific basis or TACs is well established, TACs have been subjected to manipulation in a political context. This has been a significant problem in the European Community and has been identified (Anon 1991) as one of the major shortcomings of the Common Fisheries Policy.

  iv. Lack of structure in recommended TACs where price differentials between age or size classes are large. This can result in targeting on specific parts of the stock or size classes with unexpected implications on overall fishing mortality rates and spawning stock abundance.

  v. Constant catch quotas in situations where stock levels vary considerably as a result of natural variation in recruitment. This can result in increased risk of stock collapse (Hannesson 1988 and Section 4 below) and varyin exploitation rates since, when recruitment is low, a constant quota will take a larger proportion of the standing stock than it would when recruitment is high.

In New Zealand, for example, quotas for several fish species were apparently set at too high a level, and the necessary reduction in TACs in response to declining stock abundance led to serious dissent between the regulatory authority and the fishermen (Francis *et al.* 1993). Although the establishment of TACs for quota management purposes imposes added responsibility on the stock assessment techniques used to calculate them (Sissenwine and Mace 1992), the recommendation of an inappropriate TAC may not always be the result of poor scientific advice. Within the European Union, the TACs agreed to by Ministers during annual TAC negotiations are nearly always higher than the amounts recommended by scientists (Corten 1996). An evaluation by the European Commission of the first 8 years performance of the Common Fisheries Policy identified this systematic raising of TACs by

politicians as one of the main shortcomings of the CFP (Anon 1991). Inappropriate TACs can also result from a lack of structure in the recommended TAC where catches are not specified by age group, size etc. This can lead to targeting on the more valuable age or size classes e.g., German pollock fisheries (Reinsch 1994) and, if the price differential is significant, in gross distortion of the pattern of exploitation from that expected under an assumption of non-targeting.

- *Inappropriate institutional arrangements*
  In most countries where quota management has been introduced, it is a Government organization which usually determines quotas and administers and enforces them. OECD (1996) have identified industry support for management arrangements as the most critical factor for successful fisheries management and, in some countries (e.g., Australia, Canada, New Zealand) significant progress has been made in moving towards a system of co-management of fisheries resources with both Government and industry contributing expertise to the development and implementation of management policy. Previous failures in quota management can often be attributed to poor institutional arrangements which kept Government and industry functions separate and which lead to a poor understanding of the industry by the scientists and managers who were setting quotas. For example, the introduction of separate TACs in multispecies demersal fisheries (such as in the European Union), and the problems which ensued as catches were landed illegally or saleable fish were dumped, highlights the lack of understanding of the operational aspects of the industry in trying to implement such TAC management. The resulting lack of confidence in the abilities of the scientists and fisheries managers made the quota system not only expensive to enforce but ineffective and virtually unworkable.

2.2 Managing capacity

One of the prime failures of quota management (see Section 2.1) has been that, without individually allocated quotas, the race-to-fish incentives have inevitably resulted in increases in capacity beyond that which is economically or biologically optimal for exploitation of the resource. At best, this has resulted in reduced economic rent being generated from the fishery and, at worst, has resulted in declines or collapses in the stock. OECD (1996) has estimated that 20 out of 23 fisheries which were managed by 'global' quotas and for which it had information showed evidence of excess harvesting capacity.

Excess capacity can be developed in a number of ways, depending on the fishery in question. Increasing efficiency, through larger or more efficient vessel and gear designs, leads to increased individual fishing power even in situations where limited vessel entry is used in conjunction with quota management (e.g. Australian bluefin tuna fishery). Where entry is not limited, capacity in the fishery can also be increased through the entry of additional vessels into the fishery. In situations where rents being generated from the fishery are minimal, capacity has usually increased by the introduction of more efficient vessels and gear by those already involved in the fishery since the alternative of attracting new entrants to the fishery involves capital costs which are usually significantly large to discourage investment. Subsidies paid to fishermen to increase capacity by building more efficient vessels are common and distort the real rate of returns in favour of excess capacity.

The response to excess harvesting capacity has often been to reduce the fishing season (or to adopt other restrictive measures) to compensate for the increasing efficiency or increasing numbers of individual vessels. This response is well documented in fisheries which have experienced excess harvest capacity situations. OECD (1996) reports that all 23 fisheries managed by global quotas for which it had information had experienced a reduction (often substantial) in the fishing season as capacity increased. Combining other management measures (such as gear restrictions or limited entry) sometimes reduced, but in no case eliminated, capacity increases. This would be expected since such additional measures address only one aspect of the capacity issue and leave the issue of increasing efficiency and fishing power unresolved.

Because of the non-malleable nature of capital in the fishing industry (Clark *et al.* 1979) it is usually difficult and painful to achieve a reduction in fishing capacity. For example, in accordance with directives from the European Commission under their Multi-Annual Guidance Program (MAGP), all member states have been set targets for reducing their fishing fleet capacity. In the United Kingdom, for example, this reduction is being achieved through a combined process of capacity reduction through decommissioning vessels and restrictions on time spent at sea. In three successive annual tendering rounds, 7% of the fleet, in GRT terms, was removed by the decommissioning process in the period 1993-1996 at a cost of 28 million pounds sterling (HMSO 1996). Further reductions are planned.

2.3 Input versus output controls and combination of controls

Input controls where limitations are placed on the number or capacity of fishing units is a commonly used mechanism for controlling exploitation and is used either alone or in combination with other measures including other input controls or output controls such as TACs. The expectation of input controlled fisheries is that input control measures alone do not adequately control fishing mortality since they do not usually place any impediment on the increase in efficiency of individual fishing units. Input controls may therefore slow, but do not prevent increases in exploitation rate. OECD (1996) found evidence of stock declines in 11 of 18 fisheries in OECD member countries which were subject to management by input controls. In situations where input controls have been successfully used (an outstanding example is in Australia's largest fishery, the western rock lobster fishery, which has been managed successfully by input controls since 1963), constant re-adjustment of the input control measures have been needed in order to limit exploitation rate to target levels. Townsend (1990) has noted that the effectiveness of input controls such as limited entry is correlated with their restrictiveness. This implies increased surveillance and compliance costs to meet ever more stringent and complicated regulations and, in the Australian western rock lobster fishery, these compliance costs have increased at a rate greater than the rate of inflation over the past 10 years. It is only in fisheries where the technology of production is sufficiently inflexible (so that changes in time used and productivity of each fishing unit are unfeasible) that licence limitation can be expected to control the expansion of total fishing capacity and fishing mortality. Such conditions are met in successful input-controlled fisheries such as Western Australia's western rock lobster fishery where Lindner (1994) has noted that the limitation on the number of pots was the effective policy instrument since the feasibility of lifting pots more than once in each 24 hours was subject to severe diminishing returns.

The economic impacts of input controls has been reviewed by OECD (1996) who concluded that, while licence limitation (either alone or in combination with other measures) may result in some economic benefits, the approach "cannot achieve maximum economic performance". They identified excess capacity and capital stuffing as the two most likely consequences of input controlled fisheries.

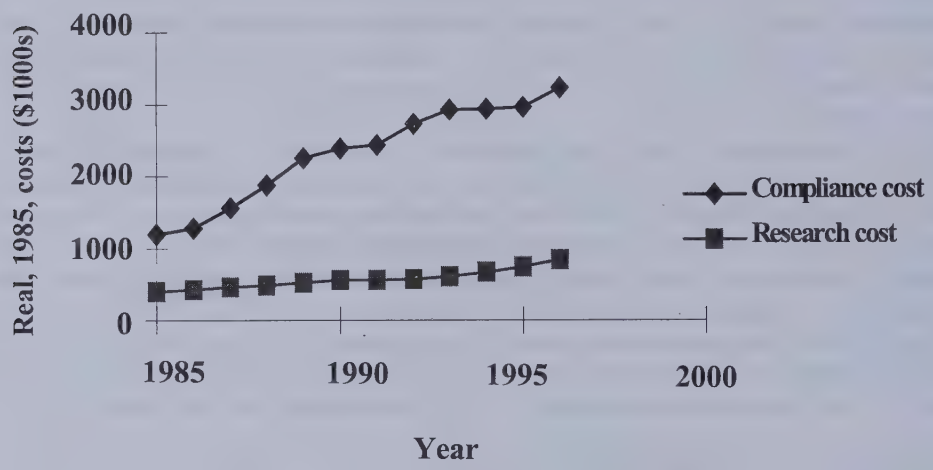

Figure 1: Real compliance and research costs (i.e. adjusted for inflation to real 1985 dollars) for the western rock lobster fishery of Western Australia. Note that, as input controls have needed to become more restrictive and complicated to control exploitation, compliance costs have risen significantly.

In a detailed analysis of the western rock lobster fishery in Western Australia, Lindner (1994) estimated that with present technology the maximum resource rent which could be generated from the fishery was $A54.7 million compared with the present (1994) generated rent of approximately $A29 million. He therefore concluded that present management arrangements resulted in rent dissipation of $A25.7 million of which $A22.5 million was due to excess capacity and $A3.2 million to capital stuffing.

2.4 Resource allocation

Allocation of scarce and finite fisheries resources occupies considerable time of fisheries management agencies, no matter whether that allocation is done within the context of a quota managed fishery or whether other management controls, such as input controls, are in place. However, within a quota management context, the issue of allocation becomes more sharply focussed since the object of the allocation decision (ie the total allowable catch) is a much more readily conceptualised and understood entity than indirect "allocation" decisions through means such as gear restrictions etc.

The decision, therefore, to move towards a quota management arrangement brings with it the need to specifically and explicitly address the question of allocation of the TAC. Such a focussing of attention on the allocation issue has often resulted in considerable political and sociological debate as to who should receive what share of the TAC. It is therefore not surprising that allocation issues have generated by far the greatest concerns and debate when a decision is made to move to quota management (see Section 5). Such a debate also introduces associated issues such as the concepts of property rights in fisheries which is discussed in Section 5.3.

The allocation of fisheries resources can be made between any number of interested stakeholders. Some of the more common resource allocation decisions which need to be made are between:

- Different segments of commercial fisheries interests (e.g. net fishermen and hook and line fishermen)
- The commercial sector and recreational fishermen
- Commercial/recreational fishermen and conservation groups
- Commercial/recreational fishermen and alternate users of the sea area (such as coastal development etc.).

The number of possible allocation decisions is only limited by the social complexity of the community and extent of multiple use of the resource.

Apart from the over-riding issue of resource sustainability, perhaps the key issue in addressing allocation issues and one which is often not given sufficient attention by Governments is the impact of allocation decisions on individual operators in a commercial fishery or individuals within other stakeholder groups. Allocation decisions within a quota managed fishery directly affect individual's income and expenditure more directly than within alternative management arrangements (such as input controlled fisheries) and therefore information on these expected financial impacts is an important background data requirement in any allocation process. For example, in the Gulf St. Vincent shrimp fishery of South Australia, a decision was taken in 1986 to re-allocate the resource to a smaller number of operators in the fishery (Morgan 1994) in return for an additional levy being paid by the remaining operators for this exclusive access. However, this decision was taken in the absence of any financial analysis of the effects of the levy on economic performance of individual operators within the fishery with the result that, even today, the operators have difficulty meeting the levy payments. This has resulted in a run down of capital investment in the fishery, marginal or negative profitability and a dissatisfied industry.

Allocation decisions therefore become a much more important issue when moving to a quota management arrangement. As a result for any such process, it should be ensured that the ability and willingness to address complex allocation issues exist before any irrevocable decision on moving to quota management is taken.

2.5 A multidisciplinary approach to quota manaagement

As can be seen from the experiences outlined above, quota management has often been introduced into fisheries as a tool to address principally concerns of biological over-

exploitation, excess harvesting capacity and inappropriate allocation of the resource. It is actually quite surprising that, although techniques such as individual quota management are often resource economists' policy tool of choice in fisheries management and that the theoretical rationale behind many moves to quota management are based on economic considerations, quotas have rarely been introduced in fisheries to address economic concerns. Rather, quota management is seen as a convenient technique, based on sound economic principles, of addressing biological issues.

This apparent lack of a comprehensive rationale for introducing quotas in many instances has often lead to a less than complete appreciation of their impacts. For example, there are few instances where the financial impact of individual operators in the fishery have been considered and only slightly more where even macro-economic implications have been taken into account. The emphasis in this current contribution is that quota management needs to be seen, and to be implemented, as a *'management system'* which affects the biological, economic and financial levels of the resource and those who exploit that resource. Only by considering quota management as such a system can the full implications and information needs be fully understood and explored.

3. ESTABLISHING THE TOTAL ALLOWABLE CATCH

3.1 Assessing a fishery's suitability for quota management

3.1.1 Single and multispecies stocks, shared stocks and straddling stocks

Perhaps the simplest situation for introducing quota management in a fisheries context is that of a single species captured by a single fishing gear. Such a situation exists in many instances, for example, the rock lobster fishery of South Australia where one species (*Jasus verrauxi*) is captured using only rock lobster traps. Introduction of a individual transferable quota management system in 1993 has resulted in a stabilisation of catches around the annual catch quota of some 1720t. However, there has been no economic assessment of the fishery following the introduction of the quota management system and there is also no information available regarding the impacts on individual operator's financial situation. However, economic impacts have probably been small because of the limited opportunities to achieve cost effectiveness with fishing gear that is essentially passive in its operation (Lindner 1994). By contrast, quota management in the Southern Bluefin tuna fishery, where fishing methodologies are such that efficiencies in capture can be readily introduced, has resulted in significant improvements in the economic performance of the fishery and in operator's profitability (Francis *et al.* 1993, Wesney 1989).

In the South Australian rock lobster fishery, industry reports, however, confirm that fishing activities have become more relaxed and the 'race to fish' which was evident in the fishery no longer exists as operators choose to take their catch in a more leisurely manner throughout the season. This has had secondary effects in the small coastal communities where rock lobster is the mainstay of the local economy. Heming[2] (pers. comm.) reports that in these communities many fishermen now choose not to fish on weekends, holidays etc. retail trading

[2] Manager, Compliance Unit, South Australian Fisheries.

has increased as fishermen spend more time in the communities and the number of regulation infractions has declined. These effects were not anticipated and were certainly not considered when ITQ management was introduced.

Thus, in general, quota management (particularly Individual Transferable Quota Management) has resulted in biological, economic and financial impacts which were broadly consistent with property rights theory (Clark 1993). In addition, the operational aspects of establishing effective quota monitoring systems and in implementing an adequate compliance program to monitor the quotas has generally been significantly easier in single species fisheries. Quota management, whether as global quota management or as ITQs, in multispecies fisheries presents rather more problems. Problems related to multispecies fisheries are not so much those of ability to determine total allowable catches or quotas for those individual species, but rather are those associated with difficulty of enforcement and operational difficulties of setting quotas for a number of species which may be captured concurrently. In many situations, e.g. in the European Union, this has led to significant operational difficulties because the setting of quotas for such multispecies fisheries ignores the reality of the harvesting process, and are therefore often impractical. Within the fisheries of the European Union (Corten 1996) this has led to a common practice in many fisheries of illegal landings and to the discarding of otherwise saleable fish because the quota for that species had been reached. Such operational difficulties also result in often insurmountable compliance problems such as in the Dutch beamtrawl fishery which takes a mixture of cod, sole and plaice. In this fishery the 500 or so vessels had individual quotas assigned for each of the three species. Catches are landed at a large number of fishing ports often on a daily basis, and the small number of fisheries inspectors were unable to enforce the individual vessel quotas. The inability to match the compliance and enforcement practicalities to the operational aspects of the fishery and to the quota regime that was introduced, inevitably resulted in a large-scale practice of illegal landings and subsequent political crises (Corten 1996).

The essential cause of these operational and compliance difficulties in multispecies fisheries can however inevitably be traced back to inadequate institutional arrangements. For example, within the European Union the policy and quota setting mechanisms are divorced from industry input and participation. This leads to impractical quota management arrangements, particularly when the complexities of a multispecies situation are considered. In countries which have a tradition of operating in a co-management arrangement between industry and government, these operational and compliance difficulties can be more easily resolved. For example, in New Zealand, a number of demersal fish species have individual quotas even though the fishery for those species is essentially a multispecies one. In setting quotas for multi-species fisheries, the operational aspects of the fishery must be known in detail and the quota rules formulated and implemented to control and monitor the switching of fishing operations to target one species or another within the multi-species fishery. However, it is usually virtually impossible to precisely estimate appropriate quotas on each individual species that is caught in a multispecies fishery, and it is inevitable that the quota of at least one of species (most probably the species with the highest value) will be exceeded. Provided that this possibility is recognised, and a suitable conservative quota established for the more valuable species, quota management can be successfully implemented in a multispecies fisheries context. But it is unlikely that either the biological sustainability or the economic optimisation goals will be achieved for the multi-species fishery as a whole. Under such

circumstances, alternative management regimes such as input controls may be successful alternatives to individual quota management.

The question of bycatch is a special situation within a multispecies fishery. Fish which are not specifically targeted and are caught incidentally to the main target species (and possibly discarded) constitute a significant potential problem in multispecies, individual quota managed fisheries. Where a quota on the primary target species exists and there is no control on bycatch species no incentive exists to minimise that bycatch. In New Zealand this issue has been addressed by establishing quotas for bycatch species as a whole and through this mechanism the quantity of bycatch which is taken can be regulated. This, however, brings the same problems as if the fishery were operating on two different species, each of which with their own individual quotas. Either the quota for the primary species is unfilled because the bycatch quota is reached first, or alternatively the bycatch quota may be exceeded as operators target on the primary species. Effective compliance issues dominate the operational practicalities of such schemes, particularly where the bycatch is not landed but discarded at sea. Under such circumstances, inspection and enforcement of bycatch quota is extremely difficult.

In summary, there are a number of significant problems in implementing individual quota management in multispecies fisheries and in fisheries where bycatch is a major issue. These problems relate principally to the operational characteristics of a fishery and to compliance issues. The problems, are not insurmountable but need to be addressed within a co-management organisational structure which brings together policy and regulatory bodies with those who have practical operational knowledge of the fishing industry. With regards to shared stocks and straddling stocks, the issue of appropriate organisational structures becomes paramount. Unless suitable arrangements exist for the adoption of a common policy position, to set individual quotas, to monitor the landings in a consistent way, and to establish an efficient and effective enforcement and compliance service, then the difficulties of implementing quota management for shared or straddling stocks will be extremely difficult. The biological and economic aspects of determining suitable individual quotas need not be any more difficult than in a single jurisdiction fishery, and hence it is the organisational structure which will determine whether the quota management system succeeds or fails. Perhaps the most significant example of such a jurisdiction is the International Commission for the Conservation of Southern Bluefin Tuna which allocates individual quotas to a number of countries in the Southern Ocean, Pacific Ocean and Indian Ocean. However, even this Commission has recently been unable to agree on quota allocation for the 1998 fishing year.

3.1.2 Impacts on long-term sustainability

The success of individual quota management in a particular fishery in achieving long-term biological sustainability will depend on a number of requirements. First, the global quota which has been set must be appropriate. This implies that the production function is approximately known and that the quota has been appropriately set in relation to this production function. Section 3.3 examines this issue in detail. Second, the year-to-year variation in stock biomass should be considered in relation to the global quota which has been set. In fisheries where there is significant year-to-year variation (for example, in many shrimp fisheries which characteristically exploit only one year class), the year-to-year variation in biomass may be significant. Under these circumstances there is the choice either to impose a

constant quota, or to adjust the year to year quota in accordance with the stock biomass. If the latter approach is adopted, it assumes that suitable research or survey programs are in place to measure this year to year variation in stock biomass in an accurate way. Section 4 examines the details of fixed and variation quotas under these circumstances.

In summary, provided that the global quota is appropriately set each year, the impacts on long-term sustainability should only be related to the interaction between the production function and the level at which the quota is set. Variable quotas can address significant year to year fluctuations in stock biomass provided such information is collected regularly and used in the quota setting process. Because of the effects of individual transferable quotas in reducing capacity, improving quality and achieving increased profitability OECD (1996), the introduction of individual quota management in a fishery should lead to improved utilisation and positive impacts on long-term sustainability of the resource. This incentive for long-term sustainability stems from the stake that the operator has, through the establishment of a form of property right in the fishery, in ensuring such long-term maintenance of the stock. The only exception to this would be where the expected rate of return from ensuring such long-term sustainability is less than the social discount rate which is acceptable operators in the fishery. Allocation of individual transferable quotas therefore becomes an important process in ensuring long-term sustainability through its effect on individual profitability. The greater the individual profitability in the fishery, the greater the incentive should be at the individual level to ensure long-term sustainability of the resource.

3.2 Assessing risks in TAC setting

In setting a TAC, whether that TAC is to be part of a 'global' quota strategy or as part of an individual quota managed fishery, it is most unlikely, even with the best scientific advice that the production function and its variance will be calculated correctly. This has been a particular problem in quota managed fisheries (see Section 2.1) and, for example, in New Zealand, TACs for a number of fisheries were initially set too high because of inadequate data and scientific analysis. This continues to be a problem in many fisheries where often the problem is not fully recognised, if at all.

This section examines the impact of uncertainty associated with a generalized production function of the form Catch=constant*fishing effort-fishing effort^{y} (and the resulting errors associated with calculated TACs) on the biological, financial and economic performance of a fishery. The uncertainties have been examined by simulating three scenarios in the estimation of the production function: first the 'correct' production function where y=2, secondly an 'optimistic' production function where the exponential term was set at 0.2 less than the 'correct' function (i.e., 1.8) and thirdly, a 'pessimistic' production function where the exponential term was set at 0.2 more than the 'correct' function (i.e., 2.2). Log-normally distributed error density functions were associated with each of the three mean production functions.

3.2.1 Biological risk associated with over-exploitation

If the estimated production function is different from the actual production function (i.e., mode mis-specification), the imposition of a TAC based on the 'incorrect' function will entail a risk that the recommended TAC will reach a level which results in overexploitation of

the resource (i.e., reducing spawning stock biomass such that it degree that it adversely affects subsequent recruitment). The size of this risk will be related to:

i. The extent of the difference between the 'correct' and the estimated production curves;

ii. The degree of natural variability in stock (i.e., levels of recruitment) abundance, i.e., the variation around the 'correct production curve;

iii. The point on the 'incorrect' production curve at which the TAC is set.

The general conclusions and implications of incorrectly calculating the production function and thereby incorrectly advising on TAC levels will depend the above three factors but general conclusions are:

i. Levels of effort (and hence mortality rates) required to take the TAC will be less than expected if the production curve is under-estimated and more than expected if the production curve is over-estimated. Figure 2 shows the relationship between the target fishing effort and the actual fishing effort which needs to be exerted to take the TAC in the case where the production curve is over- or under-estimated. If the production function is overly optimistic, then the level of fishing effort required to take the TAC quickly reaches a point where it is significantly greater than the 'target' level. However, if the production curve is 'conservative' and under-estimates the true production curve, the actual level of fishing effort required to take the TAC will always be less than the target or expected level and actually declines at higher levels of 'target' fishing effort. This result re-enforces the elements of the 'precautionary approach' (FAO 1996) in situations where datas, analyses and recommended TACs are uncertain.

ii. If the production function is over-estimated (i.e., the 'optimistic' scenario), then TACs will be set too high and hence the probability of achieving the TAC will be reduced and potential catch may be forgone. Likewise, if the production function is under-estimated, then the probability of achieving the TAC will be increased. Figure 3 shows the relationship, for the model examined, between the probability of achieving the TAC and the level at which the TAC is set. As expected, if the TAC is set at the point where the maximum yield is expected to be obtained on average, then this will achieved or exceeded 50% of the time. If the TAC is set above this level (either through errors in the production function by being too optimistic or by aiming for a higher level for some other reason) then the probability of achieving this will be reduced. Section 4 in examining the relative merits of fixed and variable quotas, also shows that the coefficient of variation of effort levels required to take a fixed TAC increases as the TAC increases. This is consistent with the conclusions of Figures 2 and 3.

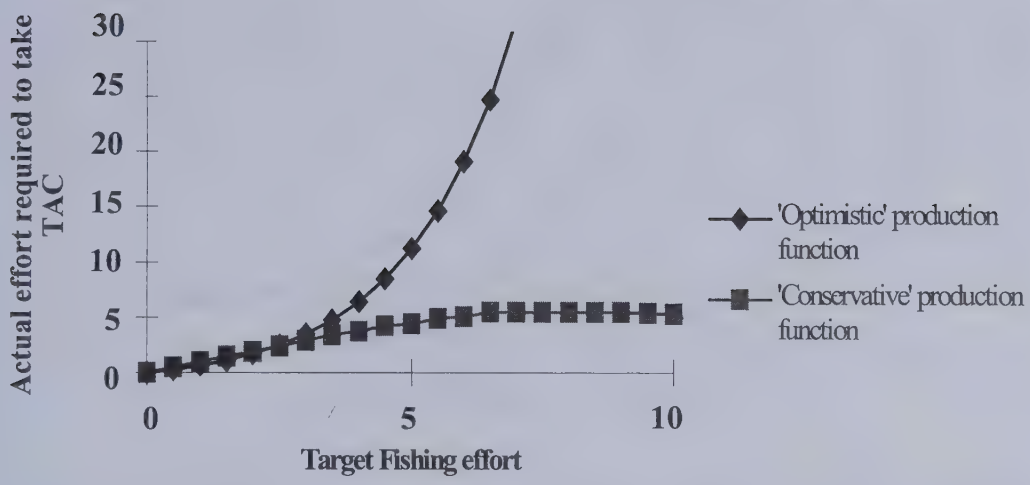

Figure 2: The level of effort required to take a given level of TAC under conditions of (i) over-estimation of the production function (the 'optimistic' function) and (ii) under-estimation of the production function (the 'conservative' function) plotted against the target fishing effort based on the actual production function. If the production function is over-estimated, the actual fishing effort, and hence exploitation rate, required to take the (optimistic) TAC increases rapidly whereas with a 'conservative' production function, this does not occur.

3.2.2 Economic risks

Both fluctuations in stock abundance and imprecisely estimated production functions will lead to the sub-optimisation of long term economic rent generated from a fishery in addition to the risks associated with over-exploitation of the resource in question. The degree to which such sub-optimisation will occur depends on the interaction between:

i. The extent of fluctuations of the stock;

ii. The level of effort required to take the TAC. This, as shown above, depends on the precision with which the production function is estimated;

iii. The actual TAC achieved, which may be different from the predicted TAC, again depending on the precision of estimation of the production function.

The extent of interaction between these three variables may be complex. However, some generalisations are possible using the modelling approach outlined above.

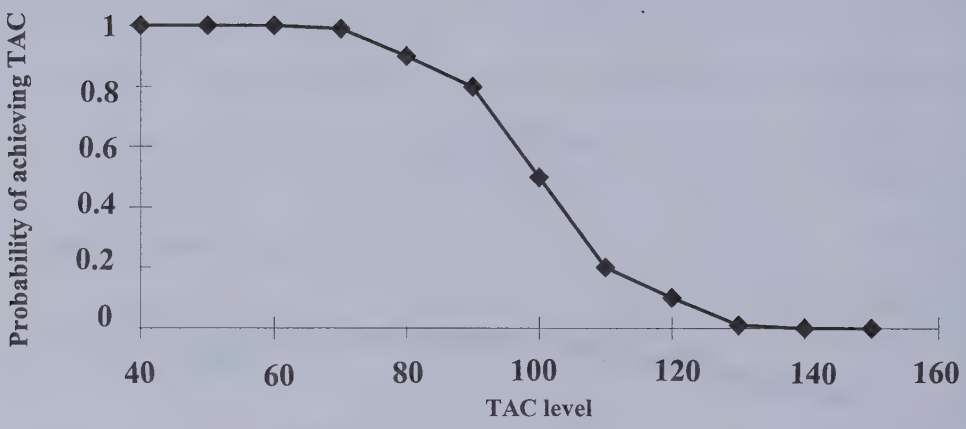

Figure 3: The probability of achieving a given TAC level for the simulation model. The TAC which produces the maximum sustainable yield is 100t and this may be expected to be achieved 50% of the time. If the TAC is set above this level through being overly optimistic regarding the production function, then the probability of achieving the TAC will be reduced. Likewise, a more conservative TAC (either deliberate or by adopting a more conservative production function) will be achieved a greater number of times.

Long term rent generation from the fishery can be sub-optimal if any one of the following occur:

i. *Revenues (i.e. TAC) are accurately predicted but costs are imprecise.* Apart from imprecision in initially estimating operational costs, this can occur because fishing effort required to take the TAC may be different to that expected. This can occur for a number of reasons including imprecise estimation of the production function. If the production function is over-optimistic, Figure 2 shows that the actual fishing effort required to take the TAC departs dramatically from the expected fishing effort level as fishing effort increases. This leads to an equally dramatic decline in economic rent generated from the fishery.

If the calculated production function under-estimates the real production function, then costs of fishing will consist of (a) the operational costs of less-than-expected fishing effort (ie. an under-estimation of costs) and (b) the costs associated with production forgone because of the conservative nature of the TAC.

Combining these two sets of costs, Figure 4 shows the relationship between the actual fishing effort required to take the TAC at the point of real maximum economic rent (in this case, a TAC of 93.75 tonnes at a value of fishing effort of 7.5, at which point net long term discounted economic rent is $46.25 million) and the losses in economic rent resulting from errors in the TAC and hence fishing effort required to take the TAC.

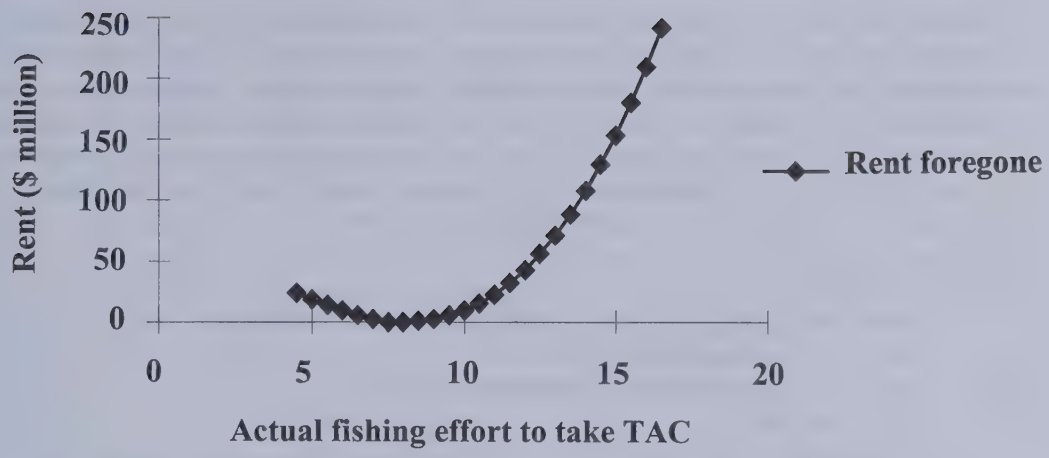

Figure 4: Rent forgone as a result of errors in estimating the TAC (and hence fishing effort) which optimises economic yield. If the TAC which produces maximum economic rent is under-estimated (eg. through the use of a conservative production function), then the fishing effort required to take that TAC will also be less than anticipated, with a small net loss of rent. However, if the TAC is over-estimated, then the potential losses of long term economic rent increase rapidly as fishing effort required to take the (optimistic) TAC increase rapidly (Figure 2) and the TAC is increasingly unable to be taken. This eventually reaches a point where economic rent losses equal the value of the fishery in perpetuity as the overly optimistic TAC can never be taken.

ii. *Revenues (i.e. TAC) are imprecise but fishing effort (and costs) are accurately predicted.* This situation can occur when there is difficulty in enforcing the TAC although the production function is known accurately. In this case, any over (or under) runs of the TAC will result in changes in actual fishing effort expended to take the TAC in accordance with the shape of the (actual) production function. Losses which accrue as a result are then due to the sub-optimal level of economic rent generated from the fishery. The relationship between these losses and fishing effort expended will be identical to those shown in Figure 4. Hence the importance of adequate enforcement of TACs is just as important as correctly estimating those TACs from a knowledge of the production function. However, in making any assessment as to the degree of enforcement required to ensure adherence to a TAC, the cost of that enforcement to achieve a given level of compliance must be considered in much the same way as the costs of research required to achieve a given level of precision in the estimation of the production function needs to be taken into account.

iii. *Both revenues (catch taken) and costs (fishing effort) are imprecisely known.* This situation is probably the most common in practical management of quota fisheries. The errors involved can relate to both an imprecise knowledge of the production function and the inability to enforce the TAC. However, as indicated above, the level of precision operationally possible (and the cost of achieving that level of precision) are important practical

considerations in estimating the total costs of the fishery in achieving a given TAC. In some instances, it may be a better option to aim for a more conservative TAC and a lesser level of compliance to the TAC than strict adherence to a more precisely defined (in terms of achieving the maximum economic benefits) TAC. In practice, both scenarios result in the same outcome but the conservative TAC/reduced enforcement option will most likely result in the least cost in achieving that outcome. Whatever the combination of errors in setting the TAC and/or estimating or measuring the fishing effort, the result will be described by the graph Figure 4 in terms of the losses resulting from the sub-optimisation of economic performance of the fishery.

3.3 Where should the TAC be set in relation to the production function?

3.3.1 Methods for determining the production function

In establishing a total allowable catch for a particular fishery, one of the first steps is to establish the production function. Because a fishery is being managed under a quota or individual quota management regime does not imply that a different methodology needs to be adopted for establishing the relationship between catch (i.e., total allowable catch) and the fishing effort which is expected to take that catch. The usual fisheries population dynamics techniques can be utilised to establish the production function, using either a surplus production model or dynamic pool analysis. Where size limits are also utilised in the management of the resource, production modelling based on historical data should be used cautiously to ensure that they refer to the same size limits or size or first capture throughout the time series.

As a result, with the usual precautions related to the establishment of production functions, there is no essential difference in establishing a production function for use in a quota managed fishery than for a fishery which might be managed by other means such as input controls.

3.3.2 Effects on economic rent generation

Given the uncertainties in establishing production functions (see Section 3.2), the rent which may be generated on average from the fishery can be related in the usual way to the difference between the steady state revenue streams as established by the production function and the costs of fishing. Such costs of fishing may include not only the operational and capital costs involved in taking the fish, but also the natural capital costs of externalities due to environmental and other impacts (see Section 3.3.3). After these costs have been taken into account, the long-term average rent from the fishery will usually be maximised at a point significantly less than the maximum sustainable yield. In addition, at this point the value of access rights to the fishery (whether those access rights are in the form of the value of tradeable quota or in the form of licence values to operate in the fishery) will be maximised. Therefore, it may be useful in a situation where access rights are freely traded to monitor such trade so as to provide a proxy for the economic rent being generated from the fishery. The allocation of the rent that is generated is the subject of Section 5.

3.3.3 Environmental and other impacts and the real costs of fishing

In assessing the costs of fishing operations, it is not only the direct operational costs of fishing operations (including the cost of capital) which need to be considered, but also the various indirect costs. These indirect costs can be related to either ***periodic*** events (ie. fluctuate around a constant mean value) or ***directional*** events (ie. trend in one direction over a long period of time, often years or decades).

Periodic indirect costs will tend to add to the real costs of fishing operations by introducing uncertainty (depending on the degree of volatility of the parameter in question) into future revenue streams. However, in situations where access rights to the resource are purchased in an open market (eg. by the purchase of quota entitlement or of a fishing licence in a limited entry fishery), periodic indirect costs can also reduce the real costs of fishing somewhat by lowering the price of access to the resource for new entrants. Among the ***periodic*** indirect costs are:

- Those related to natural year to year fluctuation in stock abundance (and hence the volatility of catches),
- Those related to market price volatility or to volatility in costs of inputs (e.g., for fuel),
- Those related to the probability of a stock collapse brought about by fishing operations.

Many periodic indirect costs will be related to fishing effort. For example, Morgan (1985) has shown that with increasing effort natural fluctuations in catch rates are increasingly translated into fluctuations in catches so that the standard deviation of catches is linearly related to fishing effort. For a given level of volatility this results in a linear relationship between discounted costs due to this volatility and fishing effort. Likewise, the probability of stock collapse (i.e., the probability of random fluctuations in abundance leading to a low enough abundance to adversely affect subsequent recruitment) is also related to fishing effort. However, in this case, the relationship is non-linear with the probability of achieving a given value of stock abundance, or below, increasing exponentially with increasing fishing effort (Figure 5).

However, the expected cost of such an occurrence involves both the probability that it occurrs together with potential loss of revenues if such a collapse occurs which is, itself, related to fishing effort in a non-linear way through the production function. This leads to the important conclusion that the real indirect costs related to the possibility of stock collapse can be significant even when the probability of such a collapse is small (Figure 5).

Indirect costs which are directional, on the other hand, will generally be independent of fishing effort but will change over time, either increasing or decreasing the costs of fishing in a systematic way. Often these trends may go unrecognised (e.g., see for example Walters and Hilborn 1995) and will not necessarily be factored into resource access values through licences etc. These types of indirect costs are, perhaps, the most difficult to deal with since management arrangements for the fishery in question will generally be unable to influence them. It is important to recognize, however, as compensatory measures (such as reducing

fishing effort) may be possible to counteract their influence on exploitation levels and consequently on periodic costs. Examples of ***directional*** indirect costs are:

- Changes in efficiency of fishing units through technological improvement
- Environmental impacts of fishing operations (eg., the impact of trawling operations on by-catch species abundance and biodiversity)
- The impact of environmental degradation on fishing operations (eg. the impact of various types of marine pollution on catches).

The various environmental impacts (including the probability of stock collapses) and influences of fishing operations are analogous to the 'natural capital' concepts which have been pioneered by Costanza *et al.* (1997) and which seek to establish 'values' of various ecosystem processes for integration into conventional economic modelling. Using these concepts, they established that 'natural capital' costs of ecosystem processes (including those related to global fishing operations) amount to approximately 1.8 times the 'direct' costs. Because they comprise a significant proportion of the total costs such indirect ecosystem costs must be included in cost considerations for a full understanding of the real costs involved in fishing activities.

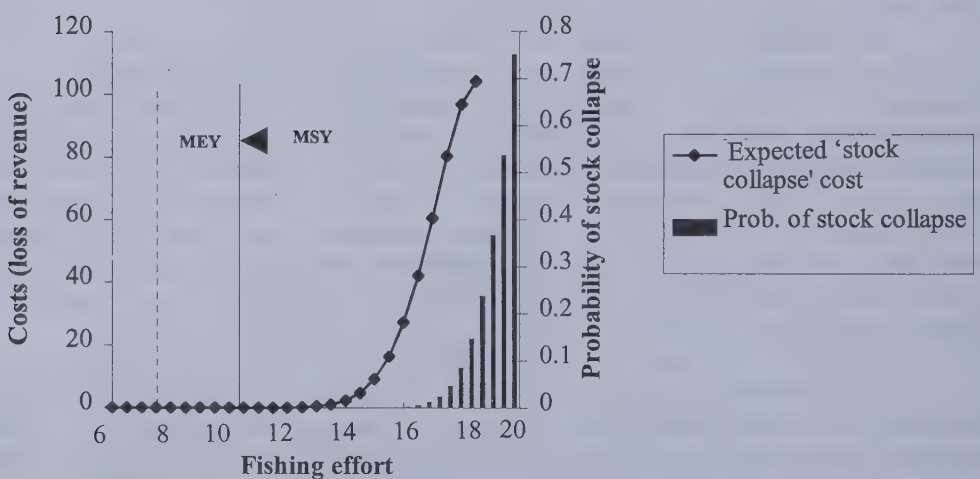

Figure 5: The probability of stock 'collapse' (i.e., probability of falling to a defined level of stock abundance or below) as a function of fishing effort. The real (expected) costs attributed to the possibility of stock collapse can be significant even when the probability of its occurrence is small. This is a result of the costs being a combination of the probability of a 'collapse' occurring and the significant loss of revenues accruing if such a collapse occurs.

Combining both the various types of indirect costs with the direct operational costs of fishing leads to the identification of the total cost of fishing. For the model fishery being examined, these total costs are shown in Figure 6 together with the revenues which might be expected to accrue from fishing operations. This cost relationship is somewhat different from the cost curve produced when considering operational costs alone and results in rapidly escalating real costs at higher levels of fishing effort. This is a result of the increasing importance of the various indirect costs at higher fishing effort levels.

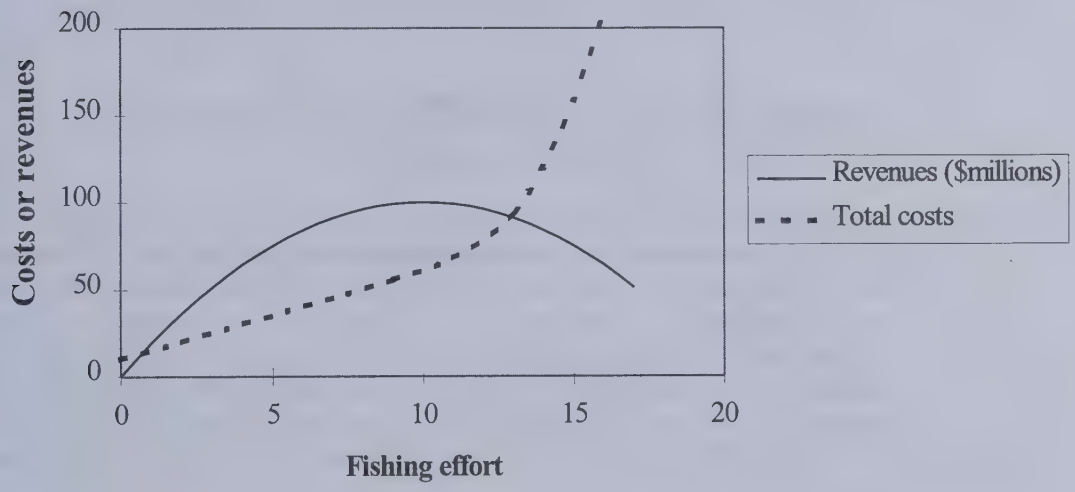

Figure 6: Changes in the total cost of fishing with fishing effort together with changes in revenues. Note that total costs increase rapidly at higher fishing effort levels as indirect costs (such as costs related to overfishing or environmental risk) become more important than direct operational costs. The precise form of the revenue and total costs relationships will vary with individual fisheries but should follow the same general functions as those above.

In fisheries where access rights are traded in an open market system (eg. the trading of quota entitlements in a quota managed fishery or of fishing licences in a limited entry fishery) the value of the right of access to the resource will reflect the present discounted and future economic rent generated from the fishery. This rent is equivalent to the discounted revenues from the fishery less the total fishing costs. Because the relationship between total costs of fishing and fishing effort is non-linear (Figure 6) then the value of the access right (such as quota or licence value) will be asymmetrically related to fishing effort (Figure 7). The asymmetry of the relationship implies that the value of access rights to the resource will decline much more rapidly as indirect costs become important. In cases where the value of the right of access can be monitored, these data may therefore provide valuable information on the total costs of fishing and the real economic rent being generated from the resource.

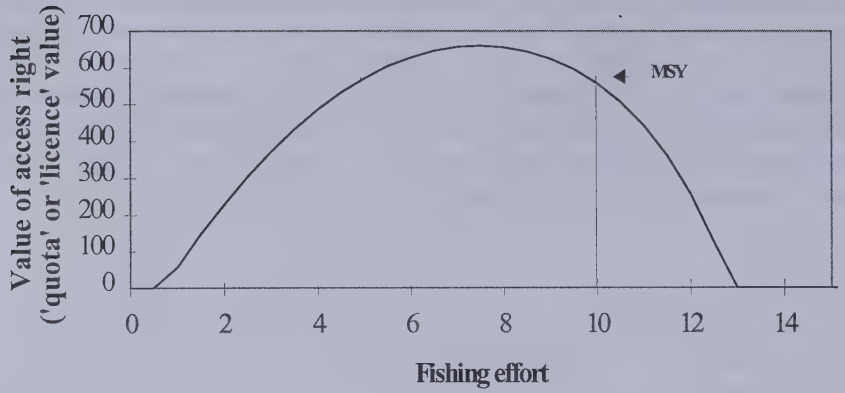

Figure 7: The implied value of access rights to a fishery, based on the discounted economic rent generated, at various fishing effort values. Note that, because the relationship between total costs and fishing effort is non-linear, the relationship is asymmetrical. In fisheries where access rights are traded (eg. quota entitlements in a quota managed fishery), these values will represent the free market price at which such entitlements are traded. The market price of entitlements will not be maximised at the point of maximum yield from the resource but at a lower value of fishing effort near to the point which produces maximum economic rent.

3.3.4 Impacts on operational costs and the affordability of cost reduction

In establishing TACs, a prime associated requirement is to provide the economic and regulatory climate for inducing minimal operational costs within the constraints of stock sustainability. Morgan (1997) examined this aspect for a hypothetical fishery under quota management with a fixed number of operators and a cost curve which was assumed to consist of a fixed cost for each operator and a variable cost which was linearly related to the level of fishing effort. Operational cost reduction was undertaken in 10 steps, each representing a 10% reduction from the original costs. The cost of achieving each step of operational cost reduction was assumed to be an exponential relationship where initial cost reductions were easier (and cheaper through technological innovation) to achieve than subsequent cost reductions.

The incentive for achieving cost reductions was measured in two ways. First a long term benefit/cost ratio was established where the long term, undiscounted resource rent generated per operator was compared with the immediate costs of achieving each step of operational cost reduction. Second, the short term 'affordability' of the cost reduction process was determined by calculating the proportion that the cost of each step of operational cost reduction bore to the overall resource rent generated per operator.

The principle conclusions of the analysis were:

i. The incentive for each step of operational cost reduction (measured as the long term benefit/cost ratio) was independent of the level of the TAC. The cost reduction incentive was also independent of the level of the TAC. The cost reduction incentive was also independent of the precise form of the operational cost/fishing effort relationship.

ii. The short term affordability of cost reduction was greatest at the original (i.e., before the cost reduction) Maximum Economic Yield and declined moving away from that point (Figure 8).

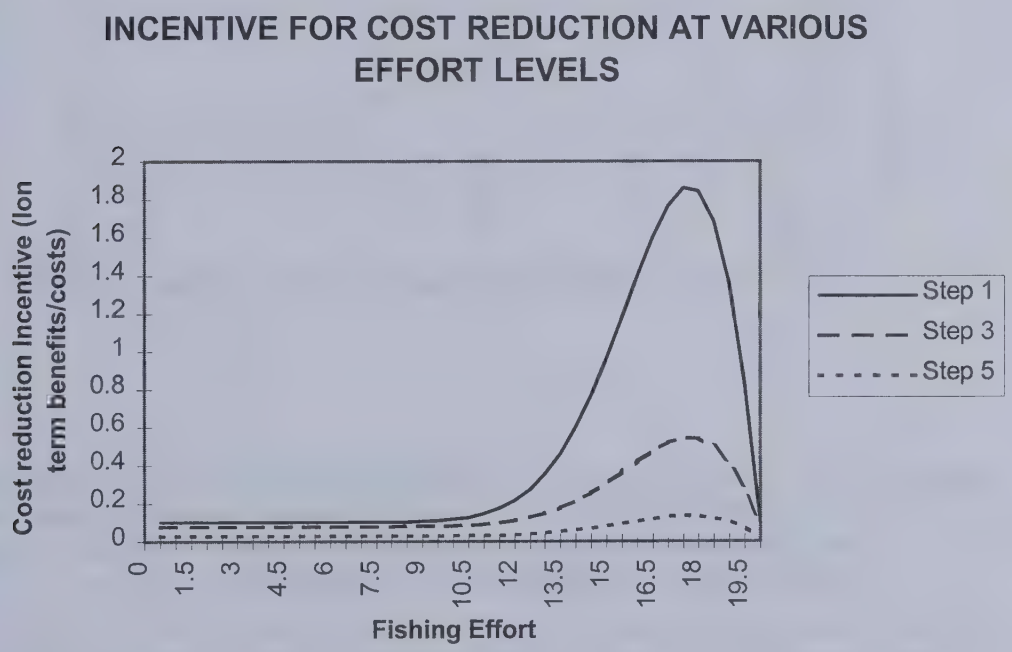

Figure 8: Incentives for achieving operational cost reductions at various levels of fishing effort for 3 different steps in the cost reduction process. The incentive is maximized at the point of Maximum Economic Yield for all cost reductions steps. This implies that financial incentives for achieving operational cost reductions will be reduced as one moves away from the point of Maximum Economic yield.

iii. The incentive for operational cost reduction increased with each step in the cost reduction process, reached a maximum and then declined (Figure 9). This implies that operational cost reduction in a quota managed fishery will at first be an increasingly attractive process before the costs of technology of achieving further reductions make those reductions increasingly unattractive.

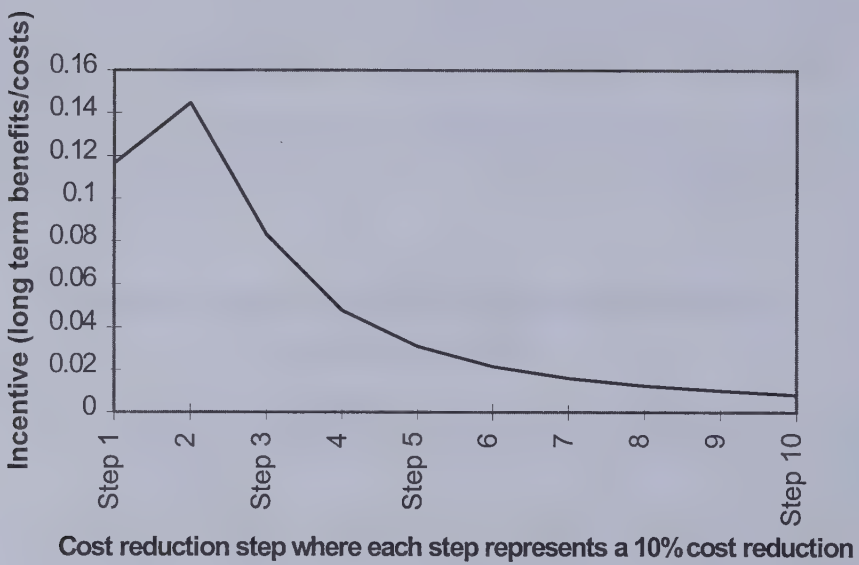

Figure 9: Incentive for operational cost reduction at different steps in the cost reduction process. The incentives for cost reductions first increase and then decline as the long term benefits become less attractive compared with the increasing incremental price of achieving operational cost reductions.

iv. For the case studied, the short term affordability was relatively flat over a wide range which encompassed both MEY and MSY. This indicates that TACs set anywhere within this range will have little effect on short term affordability of operational cost reduction.

v. The short term affordability of operational cost reduction decreased rapidly as the (original) point of zero economic rent generated is approached and a discontinuity existed at the point of zero economic rent (Figure 10).

vi. Year to year variation in fishing effort required to take a fixed quota under a scenario of variable recruitment increased rapidly as the TAC level approached MSY (see below and Figure 11) although at MSY, this variability declined as quota could not to be taken in all years.

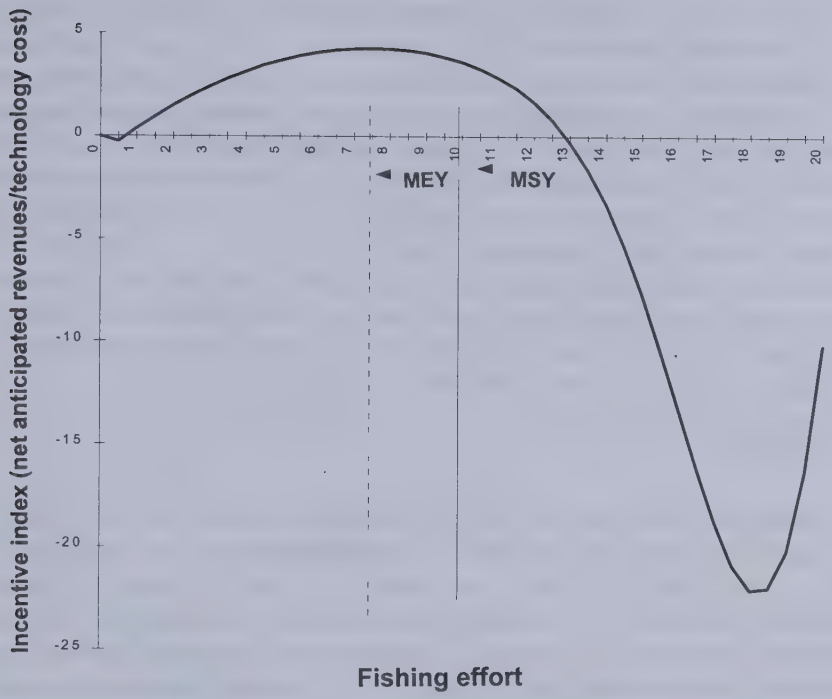

Figure 10: Changes in the incentives for achieving operational cost reduction measures at different levels of fishing effort. The incentives for achieving operational cost reduction measures are maximised and are most affordable when the TAC is set around Maximum Economic Yield (MEY).

In summary, if quotas are to achieve the aim of maximising economic efficiency, there needs to be both a long term incentive for achieving cost reductions and those cost reductions need to be affordable in the short term. Long term incentives for cost reduction have been shown to be independent of fishing effort levels while the affordability of those reductions is maximum at initial MEY. Year-to-year variability in fishing effort required to take a quota is high at MEY and may be higher than at the point of MSY. Therefore, given that biological risk of stock reduction is also greater at MSY than at lower levels, quota levels might best be set near MEY and be adjusted upwards to new MEYs as costs are reduced. It is unlikely that optimal quota levels will ever be at MSY.

3.3.5 Maximising incentives for operational efficiency

As has been seen above, the incentives for achieving operational cost reductions are maximised at the point where economic rent from the fishery is maximised. However, as the effects of individual quota management become apparent, and operational costs are reduced, the point at which economic rent from the fisheries maximised will change. In general, this change will be in the direction of the maximum sustainable yield so that as total costs are

reduced, the point of maximum economic yield will approach the point of maximum sustainable yield.

Therefore, it is important in any fishery managed with individual quotas to not only monitor the economic performance of the fishery, but also to ensure that incentives for continuing the operational cost minimisation process are maintained. The most effective way of achieving this is to make periodic adjustments to the Total Allowable Catch so that the annual TAC remains at the point of, or near, maximum economic rent. In this way, the incentives for achieving operational cost efficiency will continue to be maximised and the process of minimising costs in the fishery will continue. In the absence of such adjustment to the TAC as operational cost efficiencies are achieved, incentives to reduce costs will diminish and the economic effects of individual quota management will gradually be diluted. At the present time, there are no known examples where a system such as this is in place. This is not surprising considering the general lack of economic and financial monitoring of quota managed fisheries that is presently undertaken.

3.4 Conclusions

If operational cost reduction is to be funded from retained profits from the industry, those retained profits need to be sufficient to generate acceptable returns on capital invested as well as to allow funding of future cost reduction initiatives. Figure 10 shows that the affordability of cost reduction initiatives decrease the further away from MEY the quota is set. This result has significant implications if quota is freely transferable through an efficient market process and potential buyers of quota are not constrained by funding through retained profits from the quota managed fishery. J. Penn[3] (pers. comm) has pointed out that, in such cases, it would be expected that the rate of transfer of quota units would follow the same relationship as that shown in Figure 9 with an increase in turnover of quota units being expected the further away from MEY the quota was set. New entrants bringing new capital to the fishery may not be so constrained by decreased affordability of operational cost reduction and could therefore benefit from the increased profits such reduction in costs would generate. Established quota holders within the fishery would be subject to such funding constraints and increasingly, as quotas were established further away from MEY, would be unable to fund further cost reductions. Turnover in quota would therefore be expected to increase.

Likewise, quota turnover might be expected to increase as the relatively inexpensive cost reductions are made and further operational cost reductions become not only less affordable to existing quota holders (Figure 8) but also less attractive as long term benefit:cost ratios decline (Figure 9). This process is obviously also important in vertical integration within the industry and in the common observed trend (as in New Zealand, Clark 1993) towards quota purchase by processors etc.

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[3] Fisheries Department of Western Australia, Waterman, Perth.

4. FIXED VERSUS VARIABLE TACs

4.1 Biological, economic and financial impacts of fixed and variable TACs

In real fishery situations, recruitment to the fishery will vary over time both in response to environmental influences and as a result of exploitation. The extent of variation will depend on the species in question while the effect of such year to year variation on the biomass of the exploited stock will depend on the exploitation rate and the extent to which older year classes contribute to the fishery.

The question of the most appropriate strategy for a quota managed fishery under a scenario of variable recruitment was examined by constructing a stochastic model in which recruitment to a fishery with five exploited year classes was allowed to vary randomly (recruitment was normally distributed with a mean of 1 and standard deviation of 1) over an eight year period (Morgan 1997). The effects of fixed and variable quotas were then examined at various levels of TAC with the variable quota being adjusted each 'year' in response to changes in stock biomass as a result of recruitment variation.

4.1.1 The effects of variable recruitment and biomass changes

As might be expected, the fishing effort required to take a fixed quota varied in accordance with the variability in recruitment. However, most importantly, the extent of such variation (measured as the coefficient of variation of effort) increased rapidly with increasing TAC (measured as the % of MSY) before declining as the MSY level was approached (Figure 11). This decline was partly a result of the inability to take these relatively high quotas in years when recruitment was low. At fixed TACs set at a level less than MSY, quota levels were reached in almost all years although the year to year variation in fishing effort needed to take the quota was high.

4.1.2 Risk assessment issues of fixed and variable quotas and effects on long-term catches

Under a scenario of variable recruitment, it might be expected that adjusting the TAC each year in response to recruitment (and stock biomass) levels would produce not only higher average catches but would also generate higher economic rents from the fishery. Within the modelling structure described above, variable TAC increased total catches over the 8 year period by 2.1% at MSY when compared with a fixed TAC. At TAC levels less than about 0.8 of the long run MSY, variable TACs actually produced a smaller total catch than fixed TACs (Table 1). Also, under a variable quota management system, the variation in fishing effort needed to take the TAC was significantly larger than the equivalent fixed quota scenario (Figure 11) except at levels a little less than MSY where variability of effort for fixed quotas was higher.

Table 1

Catches over an 8-year period under fixed and variable quota management systems with variable recruitment

QUOTA LEVEL (% OF MSY)	CATCH (FIXED QUOTA)	CATCH (VARIABLE QUOTA)
0.2	160	144
0.4	320	311
0.6	480	474
0.75 (MEY)	600	592
0.8	640	638
1.0 (MSY)	767	790

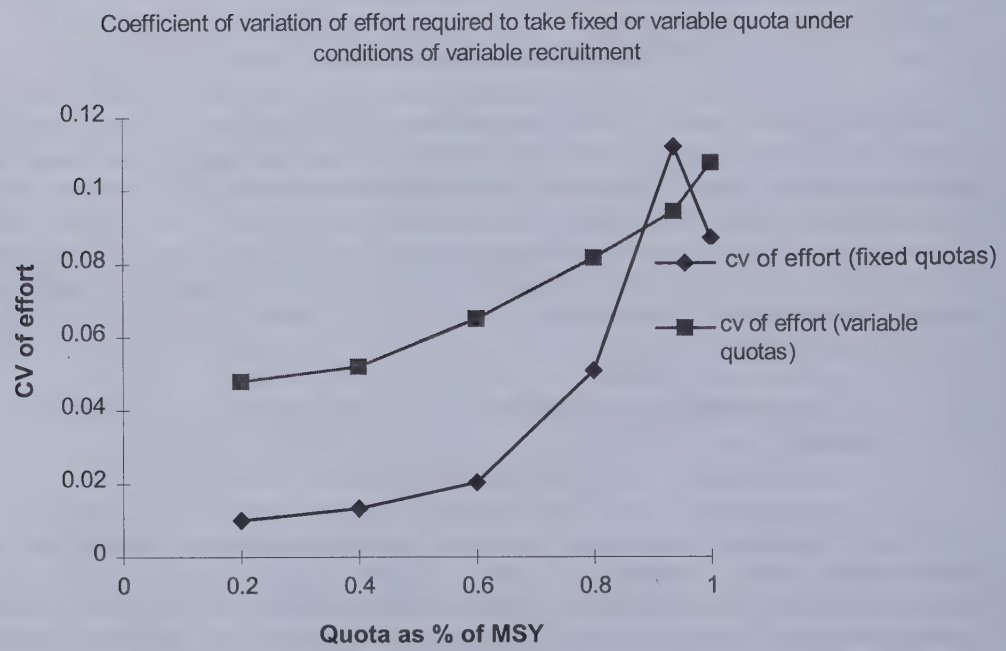

Figure 11: Variation in year to year fishing effort required to take fixed and variable quotas. Note that under variable quotas, the variation in fishing effort to take the TAC will be generally be greater than with fixed quotas.

The discounted economic rent generated under a fixed and variable quota system was also examined using the above modelling technique and using a discount rate of 7%. Figure 12 shows that in general, fixed quotas produce higher levels of economic rent from the fishery at all levels of TAC except at a point a little less than MSY (in this case, at MEY) where variable quotas produced higher economic rent levels. This difference is related to the increased variability of fishing effort required to take a variable quota which results in uncertainty over long-term licence valuations and hence a long term reduction in discounted rent generated.

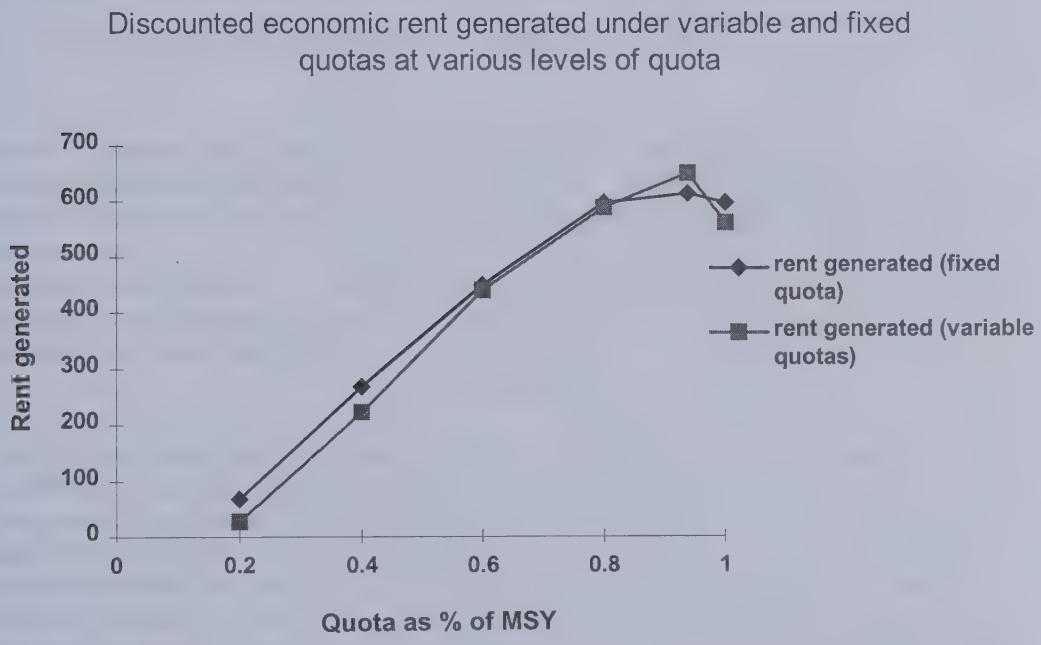

Figure 12: Changes in discounted economic rent generated under fixed and variable quotas at different levels of TAC. In most instances (apart from near MSY) fixed TACs or quotas usually generate more economic rent than variable TACs. This is partly due to the larger variation in fishing effort (and hence costs) required to take a variable TAC than a fixed TAC.

In summary, variable TACs or quotas, adjusted in accordance with random variations in recruitment result in significantly higher levels of year to year variation in fishing effort required to take the TAC than is the case with fixed TACs. Also, because the TAC or quota is adjusted each year in response to stock biomass, the total long term catch under a variable TAC system is generally less than with a fixed TAC management system. This implies that variable TACs or quotas may offer more protection to the stock which may be important if the TACs are set near MSY or if stock abundance is low. In most instances, the long term economic rent generated from the modelled fishery is greater under fixed TAC management than with variable TACs or quotas except at points approaching MSY. This greater long term

economic rent which is generated under a fixed TAC management regime results in the value of access rights to such a fishery being higher than what they would be under a variable TAC management structure. As indicated above, this difference in access right value is partly related to the greater stability in fishing effort required to take a fixed TAC than what there is under a variable TAC management scheme.

Since the modelling techniques used in this analysis were generalised production and cost functions which are applicable to many fisheries, it is believed that these results have general application. However, similar analyses need to be undertaken for specific fisheries as part of the information requirements for effective quota management and for analysis of the implications of such management.

4.2 Conclusions

The decision of whether to manage by fixed or variable TACs or quotas is therefore very much a trade off between the extent of stock (particularly breeding stock) protection that is considered necessary and the objectives of maximising economic rent and minimising effort variability. If TACs are set at levels near MSY, the biological risk of, and costs associated with, a stock decline may be significant and hence management by variable TACs will usually be the preferred option. However, if TACs are set at lower levels (particularly near MEY), fixed quotas will usually produce greater long term economic rents while minimising the variability in fishing effort required to take the quota.

Examples of fisheries which have a regular annual system of adjusting the TAC in response to stock biomass or recruitment levels are surprisingly rare although there are numerous examples of fisheries, particularly in New Zealand, Australia and Canada where TACs have been adjusted in response to either a crises in the fishery or as a one-off adjustment. For example, the TAC of a *Sardinops* fishery in Western Australia was reduced from 5500t to 3700t in 1995 in response two years of poor recruitment of juveniles with a computer simulation model of the fishery being used to guide the TAC adjustment process (Fletcher 1995).

Another example of a fishery that adjusts the total allowable catch in response to stock abundance is the fishery for pilchards (S*ardinops* spp.) in South Australia. In this fishery the quota was increased from 3 500t in 1997 to approximately 11 000t in 1998. In order to avoid the problems of over-capacity in this fishery, the additonal quota was allocated through a tender process for one year only. The allocation of the Total Allowable Catch has therefore become a two-tiered process with a core quota and a variable additional quota which is auctioned or tendered to the highest bidder.

5. ALLOCATING A TAC

OECD (1996) identified the initial allocation of quota or TAC as the single greatest problem (together with enforcement and compliance) in the implementation of ITQ management in fisheries in the OECD countries. In their study, they identified the initial allocation of individual quota as one of the most difficult, time consuming and costly aspects of implementing an ITQ management scheme. The initial allocation is often difficult and

controversial because it determines who will receive many of the benefits from the program, creating a valuable asset for some and excluding others. Initial allocations are commonly done on the basis of catch history, but the allocation formula used can result in very different allocations for individual and segments of the fishery.

Because of the way in which most allocation decisions are determined, the allocation process usually results in an (often substantial) windfall gain to those who are successful in the allocation process (Morgan 1995). With substantial rewards at stake, it is not surprising, therefore, that difficulties in the initial allocation of TACs have often lead to severe discontent and legal action over the allocation process (e.g., National Fisherman 1994a, 1994b).

5.1 The allocation of TAC between participants in the fishery

Once a TAC has been established, the question of the allocation of that TAC becomes important. There are basically two levels to the allocation problem; the first is the allocation between the participants in the fishery and the regulating agency/community and the second is the way in which the TAC is allocated among the participants.

The first level of this allocation problem involves a division of the resource rent generated from the fishery between the participants and the community, for whom the (usually Government) regulating agency acts. To address this issue, a knowledge of what resource rent is being generated is required and often this is not available. Therefore the practice has been for the government to impose an initial minimal resource rent levy (in the form of a management fee or tax) with a commitment to increase such fees over time so that the government is eventually the major beneficiary of the resource rent generated. For example, the 'management fee' for the Australian bluefin tuna fishery was initially set so as to recover 38% of attributable management costs (Wesney 1989) but with a commitment to move towards full management and partial research cost recovery (Anon 1994). Thus, without a detailed knowledge of the resource rent being generated (or how it was changing over time in response to quota management) an incremental approach was adopted which presumably could be halted when it was seen that the allocation process was 'optimised'. During this process, economic rent from the fishery might be expected to increase as the incentives for operational cost reduction take effect. As a result, an incremental approach to resource rent allocation will constantly re-adjust itself to changing circumstances without a knowledge of how that rent was generated. Rent generated by use of the community resource will be treated in the same way as rent generated through operational cost reduction by the fishermen. Such an approach will therefore have significant impact on the 'affordability' of future cost reductions (see above) and may either hinder the process of cost reduction or lead to increased market turnover of quota.

In most fisheries to date, the initial quota fee or price has been set so low that quota holders have enjoyed a windfall gain. This may be useful in initially encouraging the acceptance of the concepts of quota management but it has also had unfortunate consequences such as encouraging speculation and, where a secondary market exits, of dissipating resource rent in subsequent transaction fees. In addition, initially low fees can attract and retain inefficient firms within the industry since the windfall profits are capitalised into the value of the original quota holder company. This problem was recognised as a significant one in the

allocation of airport slots at US airports (Grether *et al.* 1981) and influenced the final design of the allocation system.

Morgan (1995) has examined the various forms of allocation of resource rent both within the fishing industry and in other industries which have had to deal with the problem of allocation of scarce resources. In all quota managed fisheries to date, the allocation of the resource rent generated from the fishery between the participants and the government has been done by administrative decision. Morgan (1995) also showed that such an allocation method is inevitably economically inefficient since it is highly unlikely that the regulatory authority would have sufficient detail of the demand structure for quotas to optimise the quota price and the rent accruing to the regulatory authority. It was interesting to note that, in all other industries examined by Morgan (1995), an evolution had taken place whereby resource rent allocation by administrative decision had been replaced by allocation through an auction or tender system. In these other industries (which covered communications, airlines and the financial industry) both theory and practice had shown that:

i. Allocation of resource rents by auction or tender was the only method which maximised economic efficiency in the allocation process, provided that the design of the auction or tender process was correct.

ii. Allocation by a suitably designed auction or tender process was able to address a wide range of both economic and public policy objectives and brought out the real costs of non-economic policy goals. This is an important point since the usual view of the auction process is that it addresses revenue goals only which, in the case of natural resource allocation, is generally not the primary goal.

As a result of the evolution which had taken place in these industries Morgan (1995) suggested that resource rent allocation issues in fisheries would eventually follow the same path once the need to provide incentives for fishermen to adopt the concepts of quota management had diminished. Since that time, Western Australia has moved to examine a process of tendering for quota in some of its quota managed fisheries although, to date, no such process has been implemented. However, the ability to adopt a tender process in quota allocation exists in most fisheries legislation in Australia and elsewhere.

Allocation of TAC between participants in a fishery can either be done together with, or separate from, the allocation of economic rent between participants and the regulatory authority. If done together, the regulatory authority becomes one more stakeholder in the allocation process and under these circumstances Morgan (1995) has shown that an auction or tender process will not only allocate resource rent in an economically efficient way (with revenues being generated which can offset the costs of management, research and development of the fishery as well as providing, if needed, a return to the wider community) but will also identify those potential users of the resource with the highest use-values for the fishery in question.

The design of the auction or tender process can be arranged so as to address a variety of non-economic goals. These non-economic goals in a fisheries context might be the protection of existing rights in a fishery, matching quota to capacity and avoiding collusive practices and monopoly situations. The extensive theory of auctions and tenders which has

been developed in response to similar problems in other industries (e.g. McAfee and McMillan 1987, Riley and Samuelson 1981) provide guidance as to appropriate designs in a fisheries context to address these problems. For example, providing designated bidders with a price preference[4] in an otherwise conventional auction design will increase the quota won by the designated bidders (who could be pioneers or existing operators in the fishery) while at the same time increasing revenues generated from the auction. Price preferences are therefore an efficient means for protecting existing or implied rights to the resource to whatever degree is considered appropriate. Similarly, Morgan (1995) showed that matching quota to capacity can be achieved in an economically efficient way by an auction design which incorporates simultaneous bidding on small quota units together with multiple rounds of sealed bids.

If the allocation of TAC between participants is done separately from the allocation of economic rent between participants in the fishery and the regulatory authority, this implies that administrative decisions regarding the sharing of resource rent between the regulator and the regulated would have been carried out first. Under such circumstances, it is difficult to envisage a process whereby an auction or tender process with two bidders (the regulator and the group of potential participants in the fishery) would first take place to determine allocation of resource rent. The resource rent allocation process is therefore restricted to allocation by administrative decision which, as shown by Morgan (1995) and above is inevitably economically inefficient and results in dissipation of resource rent. To date, this process has been the norm in quota managed fisheries, particularly in Australia, with resource rent allocation being done through a process of 'cost recovery' for specified management, compliance and research costs related to the fishery. Such 'cost recovery' principles have also been applied to non-quota managed fisheries as a means of allocation of economic rent. In the fishery for the western rock lobster, which is Australia's largest fishery, management by effort limitation (input controls) has been estimated by Lindner (1994) to result in significant dissipation of economic rent. Moreover, under the present management arrangements for that fishery, economic rent is unlikely to exceed 69% of the potential rent able to be generated under alternative (i.e., transferable quota) management arrangements.

5.1.1 Taking previous catch history into account

The allocation of the TAC between participants in quota managed fisheries has been the subject of significant ingenuity to take into account previous history in the fishery. Perhaps the most successful of these methods is the 'Adjusted Preferred Method' pioneered in South Australia, which essentially gives participants the choice of how they want previous catch history in the fishery to be taken into account (average catch over the last x years, catch in the best y of x years, catch in the previous season etc) and then adjusts the total back to the established TAC, resource rent allocation issues having been previously and separately addressed through a 'cost recovery' process. At the other extreme, in fisheries such as the Western Australian abalone fishery, allocation between participants is based simply on an equal share of the TAC for all participants with, again, resource rent allocation being separately dealt with through a 'cost recovery' process.

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[4] Price preferences, which are essentially a premium applied to the bid or tender price (so that, for example, a $10 bid with a 20% price preference becomes a $12 bid for the purpose of the tender or auction) are an important tool in this regard.

The most efficient method of taking previous catch history into account (Morgan, 1995) has been shown to be an auction or tender system which is suitably designed so that a price preference is given to individuals in accordance with their previous catch history. Such allocation processes effectively and efficiently increase the amount of quota which can be run by a designated bidder in an auction or tender process, while at the same time increasing revenues generated from the auction or tender process. Even with such a process, however, the question remains of which catch history is to be taken into account. In practical situations, this has been the subject of significant dispute where operators variously argue for the best of the last x number of years, the average of a number of years or other variations on catch history. These questions cannot simply be resolved objectively and are essentially a political and sociological issue to be dealt with by negotiation within each fishery.

5.2 The allocation of economic rent

The allocation of economic rent generated from a fishery between the participants in the fishery and the regulatory authority is most efficiently dealt with when the two processors are considered together (see Section 5.1). The proportion of the economic rent which is generated from a fishery which is allocated to the regulatory authority will depend not only on the socio-political context in which the fishery is operating, but often also on the total rent generated and the profitability of the fishery. Regulatory authorities often find it easier to extract a proportion of the rent from a profitable fishery than what they do from a marginally profitable one.

In considering the relative proportion of rent which accrues to the regulatory authority and that which is retained by the operators of the fishery as profit, an important consideration is to ensure that the fishery remains sufficiently profitable for the operators to encourage reinvestment of profits when required. In Section 3.3.3 it was shown that the incentives for reducing operational costs in the fishery depend, as one would expect, on the rent which has been generated from the fishery in terms of profits to the operators. If, in the allocation process, a significant part of the rent generated is claimed by the regulatory authority, then the profitability of the fishery will suffer and the overall economic benefits one might expect from an individual transferable quota management system may not result.It is therefore in the interests of both the operators in the fishery and the regulatory authorities to allocate rent so as to ensure a profitable fishery whereby profits can be reinvested in cost saving measures. This reinvestment inevitably needs, as was shown in Section 3, to increase the total rent generated, to the benefit of both the operators and the regulatory authority.

5.2.1 Minimising rent dissipation

It is important that the rent which is generated from a fishery is allocated between the participants in the fishery and the regulatory authority in an economically efficient manner. This means that measures need to be implemented to minimise rent dissipation in the allocation process. Rent can be dissipated in a number of ways during the allocation process. Perhaps the most important is for the access rights to the fishery to be inappropriately valued so that the true market price of that access right is not reflected in the price and hence, rent that is generated. An extreme example is where quotas have been allocated to operators in the fishery at low cost, resulting in a significant windfall gain to those operators. In Section 5.1 it was shown that a suitably designed auction or tender process was the only mechanism which

resulted in the minimisation of rent dissipation through this process. Another important source of rent dissipation in an Individual Transferable Quota managed fishery is the transaction costs where secondary markets exist. For example, in New Zealand the initial design of the quota exchange was such that transaction costs were significant. Partly as a result of this most transactions bypass the official quota exchange and were done on an informal basis. The cost of administering and operating the quota exchange was significant, and eventually led to its ceasing effective operations. An effective secondary market for quotas in an individual transferable quota managed fishery is usually necessary to correct inefficiencies in the initial allocation process. The transaction costs and the efficiency of operation of the secondary market need to be considered to ensure that its operation does not result in significant rent dissipation.

5.2.2 Taxes, levies and cost recovery

The various ways in which regulatory authorities allocate part of the rent which is generated from a fishery to themselves varies between countries. In countries of the European Union and in Iceland a levy is placed on landings so as to secure for the regulatory authority part of the rent that is being generated from the fishery. In Mauritania, a tax is levied on the lucrative squid fishery which essentially achieves the same effect. In cases where levies or taxes are imposed, the charges made by the regulatory authority are simply a fee for access to what is generally perceived as a common property resource. The level of such tax levy or access fee varies significantly between countries and is generally related to the profitability of the fishery in question. In New Zealand and Australia, where individual transferable quota management now has a significant history, the methods of allocating a proportion of the generated economic rent is usually based on a charge for services via the regulatory authority to the fishery. The rationale behind this approach is that the beneficiaries of the fishery (i.e. generally the commercial operators) should be expected to pay for the Government's cost of managing the fishery, enforcing regulations and undertaking research. This approach has also been used in Australia where the full government costs of servicing many of the major fisheries in Australia are now recovered from industry through licence fees.

But, this cost recovery process has been difficult to implement in practice and has often resulted in significant disagreement as to the level of service which is required for the management of the fishery and which industry is expected to pay. The difficulty arises because the incentives under a cost recovery process are for those costs to be minimised since the benefits of such cost reductions or service cost flow immediately back to the operators in the fishery through reduced licence fees. Morgan (1997) suggested that a solution to this problem would be a cost recovery process whereby cost savings which are achieved by the provider of the management regulatory or research services are shared equally between the beneficiaries (i.e. the operators) and the regulatory authority. In this way, there then exists a shared incentive to reduce service costs to the fishery.

Within a cost recovery environment there is a significant danger that the servicing of the fishery becomes entirely cost-driven and the quality and extent of management compliance and research services suffering accordingly. Recent advances in both Australia and New Zealand are addressing this issue, either by establishing minimum core services that are necessary to service a particular fishery (e.g., Western Australia), or in establishing formal service agreements (e.g., as in New Zealand and South Australia) which specify not only the

level and cost of service to be provided but also establish minimum quality standards for these services. But, it remains to be seen if a process based on the recovery of costs attributable to the management of a commercial fishery can be efficiently and cost-effectively administered. Some of the more difficult problems in this area arise where a resource is captured by both the commercial operators in the fishery and, for example, recreational fishermen. In such cases the attribution of management, compliance and research costs to the commercial fishery becomes the subject of significant negotiation and often disagreement. If a process based on the recovery of fees for specified services cannot be satisfactorily resolved, then it is likely that the allocation of a proportion of the rent to the regulatory authority will revert to an access fee levy or tax with those charges being loosely related to the extent of services provided.

5.2.3 The effects of separating economic rent allocation from TAC allocation

The separation of the allocation processes leads to a situation where allocation of economic rent must be done by administrative decision although it is conceivable that the allocation of the TAC between participants in the fishery may be done by tender or auction. The overall process will therefore be economically inefficient despite the efforts that may be made to make the allocation between participants efficient and equitable through processes such as the adjusted preferred method. If overall allocation of resource rent is to be done in the most economically efficient and equitable manner the two components of the allocation process need to be addressed together preferably through a well designed auction or tender process.

5.3 The impact of allocation approaches on resource ownership and property rights

The process of allocation of fisheries quotas confers upon the individual or group receiving the allocation a right of harvest of the resource in question. More importantly, quota allocation (as opposed to input controls) separates the functions of harvesting from that of resource management so that the property rights implied in catch quota allocation can be recognised and valued according to the efficiency with which those harvesting rights are utilised. This right of access is generally a 'bankable' commodity (Townsend 1992) with its value depending not only on the proportion of economic rent that can be derived from the right of access but also on other less tangible factors such as the confidence in the long term management arrangements for the fishery (security of tenure to the access right), volatility of stock abundance, market prices, etc. The present value of the right of access is usually reflected in the price at which the access rights are sold in the open market or, if the rights are not traded, in the long term discounted economic rents generated from the fishery.

There has been much discussion on the issue of resource ownership and property rights in fisheries and the identification of access rights (through quota allocation) as one form of property right to the resource should be viewed in the context of a continuum ranging from no implied property rights in the case of open access fisheries through to exclusive collective territorial rights (e.g., as in Japanese villages - Asada *et al.* 1983) to well defined individual property rights in the case of leased areas of ocean for ranching purposes or monopoly rights to exploitation of specific stocks (e.g., some shrimp stocks of Madagascar and Australia). This situation is therefore analogous to the evolution of land-based property rights which occurred in most western countries over the past 400-600 years and, most importantly, which evolved

in response to the same general type of use pressures, overexploitation and resource and environmental degradation which is common in fisheries today. This evolution in land-based property rights also proceeded, over several centuries, from open access to forest and other areas through controlled group access for specific purposes (e.g. grazing stock) to the well defined individual freehold title concepts of property ownership which exist today. The situation of property rights through either common property or the allocation of catch quota in fisheries is analogous to the medieval practice of allocating user rights to areas of forest or grazing land.

However, it is important to recognise that resource ownership and the conferring of property rights in whatever form do not, in themselves, guarantee sustainable resource use. Individual investment, exploitation and development decisions will still be made, even under a well defined system of property rights, by reference to the economic returns available from alternative uses of the resource (i.e., the commercial discount rate). If the opportunity rates of return are such that better returns can be achieved by the non-sustainable exploitation of the resource and investment of the profit in other activities, then this may be done. This has occurred in a number of land-based activities, such as forest resources in former Yugoslavia where the transfer of forest areas to private citizens often resulted in their rapid destruction since it was more attractive for individuals to sell the trees to large forest logging companies and purchase timber than it was to sustainable manage 'their' piece of forest. Clark (1975) demonstrated that the most economically rational use of southern ocean whale stocks was non-sustainable exploitation over a short period and investment of the profits in non-fisheries activities.

Troadec (1995) has also pointed out the importance of the geographical scale of property rights in fisheries. If resources are to be managed in such a way that economic incentives exist for the long term sustainability of those resources, then the 'ownership' of the resource (as well as the institutions that govern that ownership) needs to be on approximately the same geographical scale as the resource itself (this is often referred to as the *exclusivity* of the rights). It is no use, for example, in establishing individual property rights over a small geographical part of a stock since activities in the area subject to property rights will not determine who can exploit the stock as a whole and consequently, will not result in economic incentives for long term sustainable management.

6. CONCLUSIONS

Aspects of the history of quota management have been reviewed and it is evident from experience in a number of countries that the management of fisheries resources solely by a total allowable catch method has not resulted in effective stock conservation or in optimal economic utilisation of the resource. In most instances where a total allowable catch has been the prime or sole method of management, stocks and harvests have declined significantly. For example total allowable catches used alone did not prevent the collapse of major herring stocks in British Columbia, Iceland or Europe. In addition, total allowable catch management has resulted in significant over-capacity in the world's fishing fleet with serious impacts on the economic viability of a number of major fisheries. Such over-capacity has been exacerbated by a program of government subsidies designed to 'ensure' the viability of domestic fishing fleets. The painful exercise of reducing capacity, both to conserve stocks

and to generate significant economic rent from a fishery, is presently being addressed, particularly within the European Union. The poor track record of quota management has resulted in a lack of confidence in this method of managing fish stocks. However, the recent development in a number of countries of a system of Individual Transferable Quotas has provided the effective economic incentives for improved efficiency, reduction in capacity and stock conservation. The record of ITQ management which subsumes the requirement for setting TACs is much more impressive than TAC management and has quickly become economists' policy tool of choice in the management of fish stocks. This paper has examined ITQ management systems from the point of view of an integrated management system. Often ITQs have been introduced to address either biological or economic objectives, whereas this paper has attempted to demonstrate that the biological, economic and financial implications of ITQ management are intimately interwoven and should be considered as a single system. The paper presents a number of guidelines for examining ITQ management in such an integrated way.

The initial allocation of a Total Allowable Catch to participants within an ITQ management system has been the greatest practical difficulty in the introduction of ITQ management regimes. This paper examines this issue and has concluded that the most efficient allocation mechanism is through a suitably designed tender or auction system of the Total Allowance Catch. Such a tender or auction system, if suitably designed, is able to address not only economic policy objectives, but also broader stock conservation and social objectives. The allocation of economic rent between operators in a fishery is, however, only one part of the allocation process, the other being the allocation of economic rent between the fishing industry and the regulatory authority. It is shown that the process can most efficiently be handled by considering the two allocation problems together, rather than trying to separate them. If they are considered as separate issues, the result is inevitably economically inefficient with a resulting dissipation of economic rent. As ITQ management regimes gain greater acceptance and more experience is gained in their operation, the management regimes themselves will become more and finely tuned to the various objectives for a fishery. This paper presents a first attempt at examining these systems in an integrated way.

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The management of fisheries by catch quotas has a long history in a number of areas and has probably been the most common method of controlling exploitation of fish stocks. However, in recent years, management by global Total Allowable Catches (TACs) has not been able to address the rapid improvements in harvesting technology and has therefore not generally been successful in limiting fleet capacity. This drawback, combined with practical difficulties of monitoring and enforcing TACs, has resulted in a poor record of achieving fish stock sustainability and of optimizing the economic performance of fisheries. However, recent advances in and adoption of the techniques of management by Individual Transferable Quotas (ITQs), which provide greater incentives for sustaining and optimizing economic performance of fisheries, have again focused attention on quota management. The increasing interest in ITQ management has, however, not been matched by the availability of a theoretical framework for quota management that considers the various biological, economic and financial influences as part of an integrated management system. This paper is the first of a projected series that not only examines the theoretical basis of quota (particularly ITQ) management as an integrated system, but also draws on practical experiences in various parts of the world to provide guidance for agencies examining quota management in fisheries. The present paper covers the biological, economic and financial issues that need to be considered in setting the TAC and in allocating the TAC both among participants in the fishery and between the participants and the regulatory agency. Later papers will address administration of the quota management system, compliance and surveillance issues and secondary markets for quotas.

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